(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 851 094 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
25.09.2002 Bulletin 2002/39

(51) Int Cl.7: **E21B 43/26**

BEST AVAILABLE COPY

(21) Application number: **97310276.7**

(22) Date of filing: **18.12.1997**

(54) **Method of fracturing subterranean formation**

Verfahrem zum Aufbrechen von Gesteinsformationen

Méthode pour la fracturation de formations souterraines

(84) Designated Contracting States:
FR GB NL

(30) Priority: **23.12.1996 US 774125**

(43) Date of publication of application:
01.07.1998 Bulletin 1998/27

(73) Proprietor: **Halliburton Energy Services, Inc.**
Duncan, Oklahoma 73536 (US)

(72) Inventor: **Surjaatmadja, Jim B.**
Duncan, Oklahoma 73533 (US)

(74) Representative: **Wain, Christopher Paul et al**
A.A. Thornton & Co.
235 High Holborn
London WC1V 7LE (GB)

(56) References cited:
US-A- 3 231 031
US-A- 4 050 529
US-A- 4 103 971
US-A- 5 499 678

- **FORMAN ET AL.: "The mechanics of rock failure due to water jet impingement" SOCIETY OF PETROLEUM ENGINEERS JOURNAL, February 1974, pages 10-18, XP002099460**

EP 0 851 094 B1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention relates to a method of fracturing a subterranean formation to stimulate the production of desired fluids therefrom.

[0002] Hydraulic fracturing is often utilized to stimulate the production of hydrocarbons from subterranean formations penetrated by well bores. In performing hydraulic fracturing treatments, a portion of a formation to be fractured is isolated using conventional packers or the like, and a fracturing fluid is pumped through the well bore into the isolated portion of the formation to be stimulated at a rate and pressure such that fractures are formed and extended in the formation. Propping agent is suspended in the fracturing fluid which is deposited in the fractures. The propping agent functions to prevent the fractures from closing and thereby provide conductive channels in the formation through which produced fluids can readily flow to the well bore.

[0003] In wells penetrating medium permeability formations, and particularly those which are completed open hole, it is often desirable to create fractures in the formations near the well bores in order to improve hydrocarbon production from the formations. As mentioned above, to create such fractures in formations penetrated by cased or open hole well bores conventionally, a sealing mechanism such as one or more packers must be utilized to isolate the portion of the subterranean formation to be fractured. When used in open hole well bores, such sealing mechanisms are often incapable of containing the fracturing fluid utilized at the required fracturing pressure. Even when the sealing mechanisms are capable of isolating a formation to be fractured penetrated by either a cased or open hole well bore, the use and installation of the sealing mechanisms are time consuming and add considerable expense to the fracturing treatment.

[0004] Thus, there is a need for an improved method of creating fractures in subterranean formations to improve hydrocarbon production therefrom, which method is relatively simple and inexpensive to perform.

[0005] The present invention provides an improved method of fracturing a subterranean formation penetrated by a well bore, which method does not require the mechanical isolation of the formation and which meets the needs described above. The improved method of this invention comprises the steps of:

(a) positioning a hydrajetting tool having at least one fluid jet-forming nozzle in said well bore adjacent to said formation to be fractured; and

(b) jetting fluid through said nozzle against said formation at a pressure sufficient to form a cavity therein and fracture the formation by stagnation pressure in the cavity, characterised in that the method further includes the step of:

(c) pumping a fluid into said well bore at a rate to raise the ambient pressure in the annulus between said tool and said well bore adjacent said formation to a level sufficient to extend said fracture into said formation.

[0006] A jetting apparatus for perforating well bores is known from US 499678, and this document describes an arrangement wherein the jets are in a single plane which is other than perpendicular to the axis of the apparatus housing. Jetting apparatus is also known for breaking rocks once a hole has been drilled into the rock (US 4103971).

[0007] The jetted fluid can include a particulate propping agent which is deposited in the fracture as the jetting pressure of the fluid is slowly reduced and the fracture is allowed to close. In addition, the fracturing fluid can include one or more acids to dissolve formation materials and enlarge the formed fracture.

[0008] The hydrajetting tool utilized preferably includes a plurality of fluid jet forming nozzles. Most preferably, the nozzles are disposed in a single plane which is aligned with the plane of maximum principal stress in the formation to be fractured. Such alignment generally results in the formation of a single fracture extending outwardly from and around the well bore. When the fluid jet forming nozzles are not aligned with the plane of maximum principal stress in the formation, each nozzle creates a single fracture.

[0009] The fractures created by the hydrajetting tool are extended further into the formation in accordance with the present invention by pumping a fluid into the annulus between tubing or a work string attached to the hydrajetting tool and the well bore to raise the ambient fluid pressure exerted on the formation while the formation is being fractured by the fluid jets produced by the hydrajetting tool.

[0010] In order that the invention may be more fully understood, preferred embodiments thereof will now be described, by way of illustration only, with reference to the accompanying drawings, wherein:

[0011] FIG. 1 is a side elevational view of one embodiment of a hydrajetting tool assembly which can be utilized in accordance with the present invention.

[0012] FIG. 2 is a side cross sectional partial view of a deviated open hole well bore having the hydrajetting tool assembly of FIG. 1 along with a conventional centralizer disposed in the well bore and connected to a work string.

[0013] FIG. 3 is a side cross sectional view of the deviated well bore of FIG. 2 after a plurality of microfractures and extended fractures have been created therein in accordance with the present invention.

[0014] FIG. 4 is a cross sectional view taken along line 4-4 of FIG. 2.

[0015] As mentioned above, in wells penetrating medium permeability formations, and particularly deviated wells which are completed open hole, it is often desirable to create relatively small fractures referred to in the art as "microfractures" in the formations near the well

bores to improve hydrocarbon production therefrom. In accordance with the present invention, such microfractures are formed in subterranean well formations utilizing a hydrajetting tool having at least one fluid jet forming nozzle. The tool is positioned adjacent to a formation to be fractured, and fluid is then jetted through the nozzle against the formation at a pressure sufficient to form a cavity therein and fracture the formation by stagnation pressure in the cavity. A high stagnation pressure is produced at the tip of a cavity in a formation being jetted because of the jetted fluids being trapped in the cavity as a result of having to flow out of the cavity in a direction generally opposite to the direction of the incoming jetted fluid. The high pressure exerted on the formation at the tip of the cavity causes a microfracture to be formed and extended a short distance into the formation.

[0016] In order to extend a microfracture formed as described above further into the formation in accordance with this invention, a fluid is pumped from the surface into the well bore to raise the ambient fluid pressure exerted on the formation while the formation is being fractured by the fluid jet or jets produced by the hydrajetting tool. The fluid in the well bore flows into the cavity produced by the fluid jet and flows into the fracture at a rate and high pressure sufficient to extend the fracture an additional distance from the well bore into the formation.

[0017] Referring now to FIG. 1, a hydrajetting tool assembly for use in accordance with the present invention is illustrated and generally designated by the numeral 10. The tool assembly 10 is shown threadedly connected to a work string 12 through which a fluid is pumped at a high pressure. In a preferred arrangement as shown in FIG. 1, the tool assembly 10 is comprised of a tubular hydrajetting tool 14 and a tubular, ball activated, check valve member 16.

[0018] The hydrajetting tool 14 includes an axial fluid flow passageway 18 extending therethrough and communicating with at least one and preferably as many as feasible, angularly spaced lateral ports 20 disposed through the sides of the tool 14. A fluid jet forming nozzle 22 is connected within each of the ports 20. As will be described further hereinbelow, the fluid jet forming nozzles 22 are preferably disposed in a single plane which is positioned at a predetermined orientation with respect to the longitudinal axis of the tool 14. Such orientation of the plane of the nozzles 22 coincides with the orientation of the plane of maximum principal stress in the formation to be fractured relative to the longitudinal axis of the well bore penetrating the formation.

[0019] The tubular, ball activated, check valve 16 is threadedly connected to the end of the hydrajetting tool 14 opposite from the work string 12 and includes a longitudinal flow passageway 26 extending therethrough. The longitudinal passageway 26 is comprised of a relatively small diameter longitudinal bore 24 through the exterior end portion of the valve member 16 and a larger diameter counter bore 28 through the forward portion of the valve member which forms an annular seating surface 29 in the valve member for receiving a ball 30 (FIG. 1). As will be understood by those skilled in the art, prior to when the ball 30 is dropped into the tubular check valve member 16 as shown in FIG. 1, fluid freely flows through the hydrajetting tool 14 and the check valve member 16. After the ball 30 is seated on the seat 29 in the check valve member 16 as illustrated in FIG. 1, flow through the check valve member 16 is terminated which causes all of the fluid pumped into the work string 12 and into the hydrajetting tool 14 to exit the hydrajetting tool 14 by way of the fluid jet forming nozzles 22 thereof. When it is desired to reverse circulate fluids through the check valve member 16, the hydrajetting tool 14 and the work string 12, the fluid pressure exerted within the work string 12 is reduced whereby higher pressure fluid surrounding the hydrajetting tool 14 and check valve member 16 freely flows through the check valve member 16, causing the ball 30 to be pushed out of engagement with the seat 29, and through the nozzles 22 into and through the work string 12.

[0020] Referring now to FIG. 2, a hydrocarbon producing subterranean formation 40 is illustrated penetrated by a deviated open hole well bore 42. The deviated well bore 42 includes a substantially vertical portion 44 which extends to the surface, and a substantially horizontal portion 46 which extends into the formation 40. The work string 12 having the tool assembly 10 and an optional conventional centralizer 48 attached thereto is shown disposed in the well bore 42.

[0021] Prior to running the tool assembly 10, the centralizer 48 and the work string 12 into the well bore 42, the orientation of the plane of maximum principal stress in the formation 40 to be fractured with respect to the longitudinal direction of the well bore 42 is preferably determined utilizing known information or conventional and well known techniques and tools. Thereafter, the hydrajetting tool 14 to be used to perform fractures in the formation 42 is selected having the fluid jet forming nozzles 22 disposed in a plane which is oriented with respect to the longitudinal axis of the hydrajetting tool 14 in a manner whereby the plane containing the fluid jet nozzles 22 can be aligned with the plane of the maximum principal stress in the formation 40 when the hydrajetting tool 14 is positioned in the well bore 42. As is well understood in the art, when the fluid jet forming nozzles 22 are aligned in the plane of the maximum principal stress in the formation 40 to be fractured and a fracture is formed therein, a single microfracture extending outwardly from and around the well bore 42 in the plane of maximum principal stress is formed. Such a single fracture is generally preferred in accordance with the present invention. However, when the fluid jet forming nozzles 22 of the hydrajetting tool 14 are not aligned with the plane of maximum principal stress in the formation 40, each fluid jet forms an individual cavity and fracture in the formation 42 which in some circumstances may be preferred.

[0022] Once the hydrajetting tool assembly 10 has been positioned in the well bore 42 adjacent to the formation to be fractured 40, a fluid is pumped through the work string 12 and through the hydrajetting tool assembly 10 whereby the fluid flows through the open check valve member 16 and circulates through the well bore 42. The circulation is preferably continued for a period of time sufficient to clean out debris, pipe dope and other materials from inside the work string 12 and from the well bore 42. Thereafter, the ball 30 is dropped through the work string 12, through the hydrajetting tool 14 and into the check valve member 16 while continuously pumping fluid through the work string 12 and the hydrajetting tool assembly 10. When the ball 30 seats on the annular seating surface 29 in the check valve member 16 of the assembly 10, all of the fluid is forced through the fluid jet forming nozzles 22 of the hydrajetting tool 14. The rate of pumping the fluid into the work string 12 and through the hydrajetting tool 14 is increased to a level whereby the pressure of the fluid which is jetted through the nozzles 22 reaches that jetting pressure sufficient to cause the creation of the cavities 50 and microfractures 52 in the subterranean formation 40 as illustrated in FIGS. 2 and 4.

[0023] A variety of fluids can be utilized in accordance with the present invention for forming fractures including drilling fluids and aqueous fluids. Various additives can also be included in the fluids utilized such as abrasives, fracture propping agent, e.g., sand, acid to dissolve formation materials and other additives known to those skilled in the art.

[0024] As will be described further hereinbelow, the jet differential pressure at which the fluid must be jetted from the nozzles 22 of the hydrajetting tool 14 to result in the formation of the cavities 50 and microfractures 52 in the formation 40 is a pressure of approximately two times the pressure required to initiate a fracture in the formation less the ambient pressure in the well bore adjacent to the formation. The pressure required to initiate a fracture in a particular formation is dependent upon the particular type of rock and/or other materials forming the formation and other factors known to those skilled in the art. Generally, after a well bore is drilled into a formation, the fracture initiation pressure can be determined based on information gained during drilling and other known information. Since well bores are filled with drilling fluid or other fluid during fracture treatments, the ambient pressure in the well bore adjacent to the formation being fractured is the hydrostatic pressure exerted on the formation by the fluid in the well bore. When fluid is pumped into the well bore to increase the pressure to a level above hydrostatic to extend the microfractures as will be described further hereinbelow, the ambient pressure is whatever pressure is exerted in the well bore on the walls of the formation to be fractured as a result of the pumping.

[0025] In carrying out the methods of the present invention for forming a series of microfractures in a subterranean formation, the hydrajetting tool assembly 10 is positioned in the well bore 42 adjacent the formation to be fractured as shown in FIG. 2. As indicated above, the work string 12 and tool assembly 10 are cleaned by circulating fluid through the work string 12 and tool assembly 10 and upwardly through the well bore 42 for a period of time. After such circulation, the ball 30 is dropped into the tool assembly 10 and fluid is jetted through the nozzles 22 of the hydrajetting tool 14 against the formation at a pressure sufficient to form a cavity therein and fracture the formation by stagnation pressure in the cavity. Thereafter, the tool assembly 10 is moved to different positions in the formation and the fluid is jetted against the formation at those positions whereby successive fractures are formed in the formation.

[0026] When the well bore 42 is deviated (including horizontal) as illustrated in FIG. 2, the centralizer 48 is utilized with the tool assembly 10 to insure that each of the nozzles 22 has a proper stand off clearance from the walls of the well bore 42, i.e., a stand off clearance in the range of from about ¼ inch (0.6cm) to about 2 inches (5cm).

[0027] At a stand off clearance of about 1.5 inches (3.8cm) between the face of the nozzles 22 and the walls of the well bore and when the fluid jets formed flare outwardly at their cores at an angle of about 2°, the jet differential pressure required to form the cavities 50 and the microfractures 52 is a pressure of about 2 times the pressure required to initiate a fracture in the formation less the ambient pressure in the well bore adjacent to the formation. When the stand off clearance and degree of flare of the fluid jets are different from those given above, the following formulas can be utilized to calculate the jetting pressure.

$Pi =$	$Pf - Ph$
$\Delta P/Pi =$	$1.1[d+(s+0.5)\tan(\text{flare})]^2/d^2$ wherein;
$Pi =$	difference between formation fracture pressure and ambient pressure, psi (6.89 kPa)
$Pf =$	formation fracture pressure, psi (6.89 kPa)
$Ph =$	ambient pressure, psi (6.89 kPa)
$\Delta P =$	the jet differential pressure, psi (6.89 kPa)
$d =$	diameter of the jet, inches (2.5 cm)
$s =$	stand off clearance, inches (2.5 cm)
flare =	flaring angle of jet, degrees

[0028] As mentioned above, propping agent is combined with the fluid being jetted so that it is carried into the cavities 50 as well as at least partially into the microfractures 52 connected to the cavities. The propping agent functions to prop open the microfractures 52 when they are closed as a result of the termination of the hydrajetting process. In order to insure that propping agent remains in the fractures when they close, the jetting pressure is preferably slowly reduced to allow the fractures to close on propping agent which is held in the fractures by the fluid jetting during the closure process. In addition to propping the fractures open, the presence of

the propping agent, e.g., sand, in the fluid being jetted facilitates the cutting and erosion of the formation by the fluid jets. As indicated, additional abrasive material can be included in the fluid as can one or more acids which react with and dissolve formation materials to enlarge the cavities and fractures as they are formed. Once one or more microfractures are formed as a result of the above procedure, the hydrajetting assembly 10 is moved to a different position and the hydrajetting procedure is repeated to form one or more additional microfractures which are spaced a distance from the initial microfracture or microfractures.

[0029] As mentioned above, some or all of the microfractures produced in a subterranean formation can be extended into the formation by pumping a fluid into the well bore to raise the ambient pressure therein. That is, in carrying out the methods of the present invention to form and extend a fracture in the present invention, the hydrajetting assembly 10 is positioned in the well bore 42 adjacent the formation 40 to be fractured and fluid is jetted through the nozzles 22 against the formation 40 at a jetting pressure sufficient to form the cavities 50 and the microfractures 52. Simultaneously with the hydrajetting of the formation, a fluid is pumped into the well bore 42 at a rate to raise the ambient pressure in the well bore adjacent the formation to a level such that the cavities 50 and microfractures 52 are enlarged and extended whereby enlarged and extended fractures 60 (FIG. 3) are formed. As shown in FIG. 3, the enlarged and extended fractures 60 are preferably formed in spaced relationship along the well bore 42 with groups of the cavities 50 and microfractures 52 formed therebetween.

Example

[0030] A deviated well comprised of 12,000 feet (3658 m) of vertical well bore containing 7.625 inch (19.06 cm) casing and 100' (30.5 m) of horizontal open hole well bore in a hydrocarbon producing formation is fractured in accordance with the present invention. The fracture initiation pressure of the formation is 9,000 psi (6.21×10^7 Pa) and the ambient pressure in the well bore adjacent the formation is 5765 psi (3.97×10^7 Pa).

[0031] The stand off clearance of the jet forming nozzles of the hydrajetting tool used is 1.5 inches (3.8 cm) and the flare of the jets is 2 degrees. The fracturing fluid is a gelled aqueous liquid-nitrogen foam having a density of 8.4 lbs/gal (1006.5 kg/m^3). The required differential pressure of the jets is calculated to be 6,470 psi (40.46×10^7 Pa) based on two times the formation fracture pressure less the hydrostatic pressure [2x(9,000psi -5,765 psi) = 6,470 psi (4.46×10^7 Pa)].

[0032] The formation is fractured using 14,000 feet (4267 m) of 2 inch (5 cm) coiled tubing and a 2 inch I.D. (5 cm) hydrajetting tool having three angularly spaced 0.1875 inch I.D. (0.476 cm) jet forming nozzles disposed in a single plane which is aligned with the plane of maximum principal stress in the formation. The average surface pumping rate of fracturing fluid utilized is 5.23 barrels per minute (13.86 dm^3/s) and the average surface pump pressure is 7,725 psi (5.33×10^7 Pa). In addition, from about 5 to about 10 barrels per minute (13.25 - 26.50 dm^3/s) of fluid can be pumped into the annulus between the coiled tubing and the well bore to create a larger fracture.

Claims

1. A method of fracturing a subterranean formation (40) penetrated by a well bore (42), which method comprises the steps of:

   (a) positioning a hydrajetting tool (10) having at least one fluid jet-forming nozzle (22) in said well bore (42) adjacent to said formation (40) to be fractured; and
   (b) jetting fluid through said nozzle (22) against said formation (40) at a pressure sufficient to form a cavity therein and fracture the formation (40) by stagnation pressure in the cavity, **characterised in that** the method further includes the step of:
   (c) pumping a fluid into said well bore (42) at a rate to raise the ambient pressure in the annulus between said tool (10) and said well bore (42) adjacent said formation (40) to a level sufficient to extend said fracture into said formation (40).

2. A method according to claim 1, wherein the jetting pressure utilized in step (b) is about two times the pressure required to initiate a fracture in said formation less the ambient pressure in said well bore adjacent to said formation.

3. A method according to claim 1 or 2, which further comprises the step of aligning said fluid jet-forming nozzle of said tool with the plane of maximum principal stress in said formation.

4. A method according to claim 1, 2 or 3, wherein said hydrajetting tool includes a plurality of fluid jet-forming nozzles, preferably disposed in a single plane.

5. A method according to claim 1, 2, 3 or 4, wherein said fluid jetted through said nozzle contains a particulate propping agent, preferably sand.

6. A method according to claim 5, which further comprises the step of slowly reducing the jetting pressure of said fluid to thereby allow said fracture in said formation to close on said propping agent.

7. A method according to any of claims 1 to 6, wherein said fluid is an aqueous fluid, preferably an aqueous

acid solution.

8. A method according to any preceding claim, which further comprises:

   (d) moving said hydrajetting tool to a different position in said formation; and
   (e) repeating steps (a) through (c).

Patentansprüche

1. Eine Methode für das Formen von Spalten in einer Untergrundformation (40), die von einem Bohrloch (42) durchbrochen wird, und welche die folgenden Stufen umfasst:

   (a) das Positionieren eines Hydrajetting-Werkzeugs (10), das mindestens eine flüssigkeitsstrahlformende Düse (22) innerhalb des vorgenannten Bohrlochs (42) neben der vorgenannten Formation (40), die gespaltet werden soll, umfasst; und
   (b) das Einspritzen von Flüssigkeit durch die vorgenannte Düse (22) gegen die vorgenannte Formation (40) unter einem Druck, der ausreichend ist, um in derselben einen Hohlraum zu erzeugen und die Formation (40) durch das Stagnieren des Drucks in dem so erzeugten Hohlraum zu spalten, und die sich weiter dadurch auszeichnet, dass die Methode die folgende weitere Stufe umfasst:
   (c) das Einpumpen von Flüssigkeit in das vorgenannte Bohrloch (42) mit Hilfe einer Rate, die den ambienten Druck innerhalb des Ringraumes zwischen dem vorgenannten Werkzeug (10) und dem vorgenannten Bohrloch (42) neben der vorgenannten Formation (40) auf eine ausreichend grosse Stufe steigern kann, um die vorgenannte Spaltung in der vorgenannten Formation (40) zu erweitern.

2. Eine Methode nach Anspruch 1, bei welcher der in Stufe (b) angewendete Einspritzdruck ungefähr zweimal so hoch ist wie der Druck, der für das Formen eines Spaltes in der vorgenannten Formation erforderlich ist, weniger des ambienten Drucks innerhalb des vorgenannten Bohrlochs neben der vorgenannten Formation.

3. Eine Methode nach Anspruch 1 oder 2, die weiter die Stufe des Ausrichtens der vorgenannten flüssigkeitsstrahlformenden Düse des vorgenannten Werkzeugs auf die Ebene der maximalen Hauptbelastung innerhalb der vorgenannten Formation umfasst.

4. Eine Methode nach Anspruch 1, 2 oder 3, bei der das vorgenannte Hydrajetting-Werkzeug eine Reihe von flüssigkeitsstrahlformenden Düsen umfasst, die vorzugsweise auf einer einzigen Ebene angeordnet sind.

5. Eine Methode nach Anspruch 1, 2, 3 oder 4, bei der die vorgenannte Flüssigkeit, welche durch die vorgenannte Düse gespritzt wird, einen bestimmten Proppanten enthält, der vorzugsweise aus Sand besteht.

6. Eine Methode nach Anspruch 5, die weiter die Stufe des langsamen Reduzierens des Einspritzdrucks der vorgenannten Flüssigkeit umfasst, und auf diese Weise das Verschliessen der vorgenannten Spaltung in der vorgenannten Formation mit Hilfe des vorgenannten Proppantes ermöglicht.

7. Eine Methode nach einem der Ansprüche 1 bis 6, bei der die vorgenannte Flüssigkeit aus einer wasserbasierten Flüssigkeit besteht, die vorzugsweise aus einer wasserbasierten, säurehaltigen Lösung besteht.

8. Eine Methode nach einem der vorhergehenden Ansprüche, die weiter umfasst:

   (d) das Umstellen des vorgenannten Hydrajetting-Werkzeugs auf eine andere Position innerhalb der vorgenannten Formation; und
   (e) das Wiederholen der Stufen (a) bis (c).

Revendications

1. Un procédé de fracturation d'une formation souterraine (40) traversée par un trou de forage (42), ledit procédé comprenant les étapes suivantes :

   (a) mise en place d'un outil à jet hydraulique (10), ayant au moins un embout formateur de jet de fluide (22), dans ledit trou de forage (42) à proximité de ladite formation (40) à fracturer ; et
   (b) projection d'un jet de fluide à travers ledit embout (22) contre ladite formation (40) à une pression suffisante pour former une cavité dans l'intérieur de celle-ci et fracturer la formation (40) par la pression de stagnation dans la cavité, **caractérisé en ce que** le procédé inclut de plus l'étape suivante :
   (c) pompage d'un fluide dans ledit trou de forage (42) à une vitesse suffisante pour augmenter la pression ambiante dans l'espace annulaire entre ledit outil (10) et ledit trou de forage (42) adjacent à ladite formation (40) jusqu'à un niveau suffisant pour prolonger ladite fracture dans ladite formation (40).

2. Un procédé selon la revendication 1, selon lequel la pression du jet utilisé à l'étape (b) égale environ le double de la pression nécessaire pour amorcer une fracture dans ladite formation, moins la pression ambiante dans ledit trou de forage adjacent à ladite formation.

3. Un procédé selon la revendication 1 ou 2, qui comprend de plus l'étape d'alignement dudit embout formateur de jet de fluide dudit outil avec le plan de contrainte principale maximale dans ladite formation.

4. Un procédé selon la revendication 1, 2 ou 3, selon lequel ledit outil à jet hydraulique inclut une pluralité d'embouts formateurs de jets de fluide, préférentiellement disposés dans un plan unique.

5. Un procédé selon la revendication 1, 2, 3 ou 4, selon lequel ledit fluide projeté par jet à travers ledit embout contient un agent de soutènement particulaire, du sable de préférence.

6. Un procédé selon la revendication 5, qui comprend de plus l'étape de réduction lente de la pression de jet dudit fluide de sorte à permettre à ladite fracture formée dans ladite formation de se refermer sur ledit agent de soutènement.

7. Un procédé selon l'une quelconque des revendications 1 à 6, selon lequel le fluide est un fluide aqueux, préférentiellement une solution acide aqueuse.

8. Un procédé selon l'une quelconque des revendications précédentes, qui comprend de plus :

(d) déplacement dudit outil à jet hydraulique jusqu'à une position différente dans ladite formation ; et
(e) reprise des étapes (a) à (c).

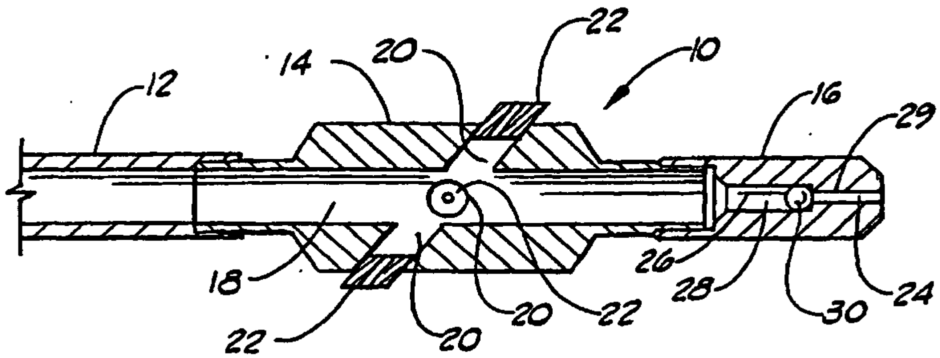

FIG. 1

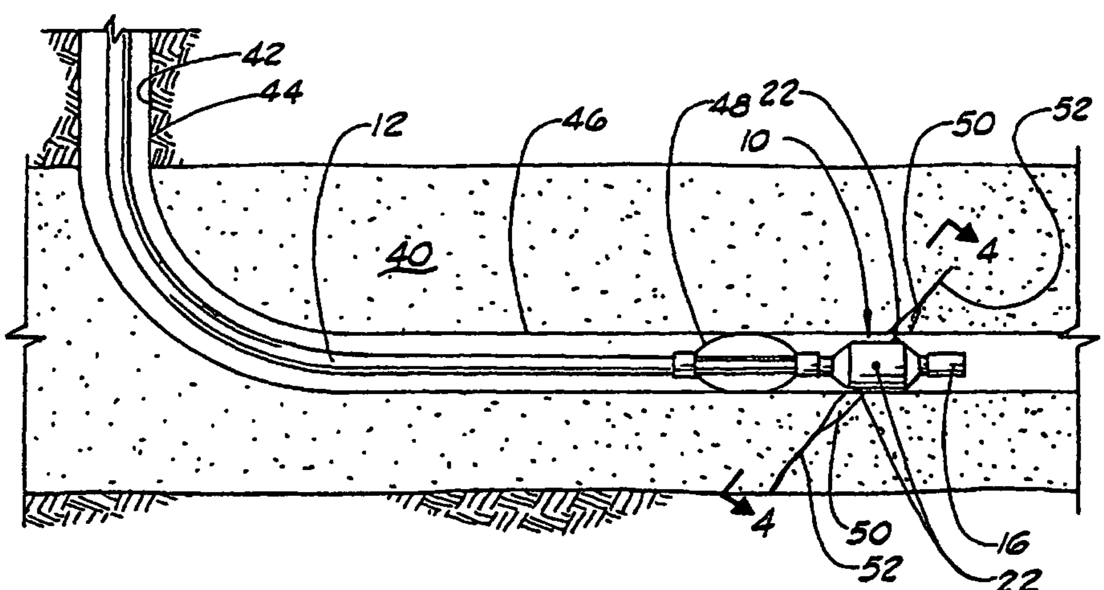

FIG. 2

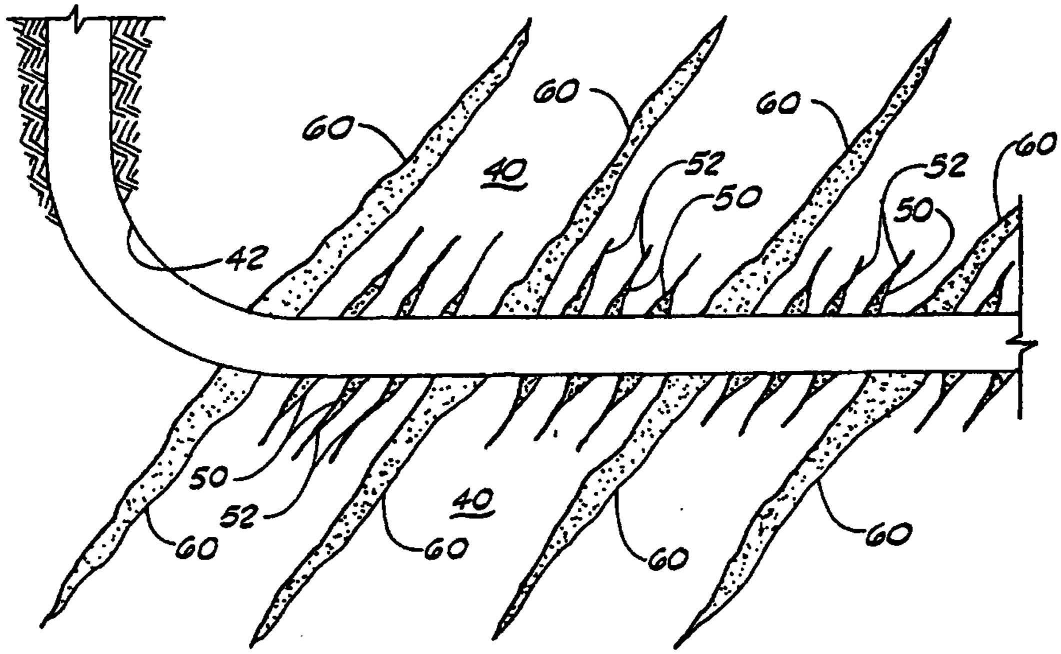
60
60
60
60
40
52
50
52
50
42
50
52
40
60
60
60
60

FIG. 3

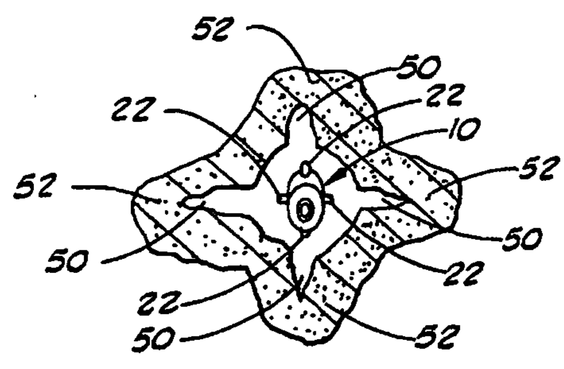
52
50
22
22
10
52
52
50
50
22
22
50
52

FIG. 4